

UNITED STATES OF AMERICA

NATIONAL TRANSPORTATION SAFETY BOARD

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Investigation of: \*

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LOSS OF THE SUBMARINE *TITAN* \*

IN THE NORTH ATLANTIC OCEAN \*

Accident No.: DCA23FM036

ON JUNE 18, 2023 \*

\*

\* \* \* \* \*

Interview of: [REDACTED] Co-designer/Pilot  
*Deepsea Challenger*

via Microsoft Teams

Friday,  
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I N T E R V I E W

LCDR [REDACTED]: Mr. [REDACTED] let's go ahead and move forward into the interview, more so about -- I'd kind of like to run the interview as like a conversation, but I will pose some questions. Feel free to expound as much you want on something.

MR. [REDACTED] Okay.

LCDR [REDACTED]: You know, we're here to hear your expertise and your guidance really.

INTERVIEW OF [REDACTED]

BY LCDR [REDACTED]:

Q. So how did you get yourself started into submersible operations?

A. Well, I'm sure you're familiar with my film *Titanic*. When I set down the path to make that film, the first thing that I did was arrange to be introduced to the head of the submersible program at the P.P. Shirshov Institute in Moscow, a guy named Professor [REDACTED]. I did that through a mutual friend of ours, a guy named [REDACTED], who is one of the preeminent underwater cinematographers in the world. And [REDACTED] had been on a submersible expedition out to *Titanic* the previous year with the Russians. And that was organized by a Canadian company that was doing an IMAX film which was released under the title *Titanica*.

When I found out that it was possible to essentially hire or charter the Russian submersible system, I wanted to meet them. So, you know, I arranged for a visa. I went to Moscow. I met



1 with Dr. [REDACTED] and we discussed the possibility of chartering  
2 his two submersibles that he co-designed, and he ran that program  
3 for the Russian Academy of Sciences. So essentially we made a  
4 deal with the Russian Academy of Sciences to charter their ship,  
5 the mothership for those two subs and -- those two very capable  
6 subs, to subsequently do an expedition to the *Titanic* wreck site,  
7 which we wound up doing in August and September of 1995, where we  
8 made 11 dives to the *Titanic* wreck and explored it and  
9 photographed it for the film. We also operated an ROV of our own  
10 construction at the wreck site at that time. We used camera  
11 systems and lighting systems of our own construction. As well, my  
12 brother [REDACTED], was a very accomplished engineer,  
13 originally from aerospace, but he was working in marine systems at  
14 the time.

15 To put backstory to that, I had been an avid diver since I  
16 was in my teens and I made a film called *The Abyss* in 1988 which  
17 was released in 1989, and I -- and as my research for that  
18 project, I got in touch of the lot of the leading lights in US and  
19 Canada on deep marine systems and a number of them worked with me  
20 on that film. So at that point, in '88 and '89, I had become very  
21 familiar with submersible operations, ROV operations, deep camera  
22 systems, deep lighting systems, and so on. Except that all of  
23 what we did for that film was all done shallow. So we used deep  
24 systems, for photographic purposes we shot them in a tank that was  
25 about 20 meters deep. So I was familiar with the hardware, I was

1 familiar with all the personnel, but I hadn't actually operated  
2 deep until our 1995 *Titanic* expedition.

3       So then I learned a lot from the Russian submersible pilots  
4 and engineers and so on about how these subs are built, how  
5 they're operated, how their tracking systems work, how their sonar  
6 systems work, how their ballast systems work and so on, because  
7 I'm engineering oriented and pretty curious. And on that  
8 expedition I went from being a sole passenger with a crew of two  
9 Russians, one of whom was an engineer and one of whom was the  
10 pilot, to essentially stepping into the shoes of the engineer and  
11 allowing us to have two pax on board with a solo pilot. Because I  
12 took over all the comms, navigation, and -- not all comms -- some  
13 comms, navigation, and sonar, as well as the lighting and imaging.

14       So I was getting essentially a crash course in deep  
15 submersibles in the *Mir* system. They were called *Mir* subs. I'm  
16 sure you're familiar with them. Very capable submersible, 6,000  
17 meter rating, three passengers -- or three occupants including  
18 pilot. Internal sphere diameter for the pilot sphere was about 2  
19 meters, so they're fairly roomy, about a -- I think it's 18 ton,  
20 18.5 ton vehicle; dedicated mothership, dedicated handling system  
21 to get it in and out of the water. So, you know, that was my  
22 trial by fire, if you will, my crash course in submersible  
23 operations.

24       We had 11 safe dives. I subsequently made, I think,  
25 somewhere on the order of 50, 5-0, *Mir* submersible dives including

1 those 11 dives, in all sorts of places, including *Titanic* on two  
2 subsequent expeditions, and then also hydrothermal vents all sort  
3 of in the 3- to 4,000 meter depth range and so on. And, you know,  
4 I became an informal pilot of the *Mir* submersibles, learning, you  
5 know, from their pilots. And then we -- if I'm going into too  
6 much detail, stop me.

7 Q. No. No, sir. It's great.

8 A. In 2002, I had the opportunity to buy the *Deep Rover*. The  
9 sub is called the *Deep Rover 2*. There were two of them available.  
10 They had been operated by a group that were working for Canal+,  
11 the big media company in France. I had an opportunity to buy them  
12 as a kind of a job lot, essentially, when they closed that whole  
13 operation down. So I bought the submersibles with a partner, an  
14 Australian named [REDACTED], who had done a lot of *Titanic* and  
15 deep hydrothermal site tourist dives. So he had been working with  
16 the *Mirs*. I knew him through that connection. He had done a very  
17 large number, I want to say in the 20 or 30 or so number of deep  
18 submersible dives with paying tourists using the *Mirs*. He and I  
19 went in as partners on the *Deep Rover 2* submersible system and we  
20 bought the entire thing, all of the support and, you know, the  
21 compressors and the diving gear and all the support  
22 infrastructure, the trailers, you know, the containers that would  
23 be transshipped and welded down onto whatever ship of opportunity  
24 we would operate those subs from.

25 And then we -- subsequently, I worked with a guy named

1 [REDACTED], whose name I'm sure you're familiar with. He runs  
2 the company Triton submersibles, and they are the largest and best  
3 of the commercial submersible suppliers and operators. He and I  
4 tore the subs apart down to every nut and bolt, reassembled them,  
5 made some electronics improvements, had them classed in the  
6 Bahamas in 2003 with ABS, and then we successfully operated those  
7 subs at numerous sites in the Atlantic and Pacific that year and  
8 the following year.

9 Then I made additional dives with the *Mir* submersibles on a  
10 later expedition to *Titanic* in 2005. Then after that, I started  
11 design and construction of my own submersible from scratch, which  
12 became the *Deepsea Challenger*, which was a 11,000 meter rated  
13 submersible. I was the co-designer of that with an Australian  
14 engineer named [REDACTED], and we built that sub in Sydney,  
15 Australia. It took us 7 years to build and then we operated it  
16 successfully in 2012. I made 10 dives in the submersible and --  
17 anyway, you can jump off from that. That's the basic sort of  
18 chronology and timeline of my expertise around submersible diving.

19 Q. I greatly appreciate it. That (indiscernible). It's very  
20 deep. I want to just back up a little bit.

21 A. Yeah.

22 Q. I just want to ask a few questions down along the line. So  
23 we discussed initially the Russian *Mir* subs. While we know a good  
24 amount about the Russian *Mir* subs, did the Russian *Mir* subs, were  
25 they -- what were they constructed of and do they have their own



1 classification system that they would utilize? And were they  
2 owned and operated by Russia or who are they owned and operated  
3 by?

4 A. It's interesting. They were developed -- [REDACTED]  
5 was one of the co-designers. He came from the Pisces system,  
6 which was an American submersible system. The Russians had bought  
7 one or two of them. [REDACTED] worked with a Finnish company. The  
8 name escapes me right now, but the subs were built in Finland.  
9 They were classed through German Lloyd's.

10 Q. Okay.

11 A. So they weren't completely -- they weren't designed and  
12 operated in Russia. They were built externally. They were  
13 classed externally, and I believe they continued to be classed  
14 right up until their retirement, through German Lloyd's.

15 Q. Great. Thank you. And then you had mentioned about the *Deep*  
16 *Rover 2*. And the *Deep Rover 2*, you said -- did you say that that  
17 was previously a tourist sub, submersible?

18 A. It was designed for exploration and for imaging essentially  
19 for media. I believe it was commissioned by the Canal+ team.  
20 They were -- that team was run by a name you'll be very familiar  
21 with, P.H. Nargeolet, and came from the *Nautilie* sub system,  
22 submersible system. As you know, he worked with IFREMER for many  
23 years and then subsequently with RMS *Titanic* using the *Nautilie*,  
24 the IFREMER sub. So P.H. Nargeolet operated the *Deep Rover 2* subs  
25 before I acquired them. I had known, you know, P.H. for many

1 years at that point, or for several years.

2 So they were not designed specifically as a tourist sub.  
3 They were designed, I would say, as an exploration class sub to be  
4 professionally operated, and that was pretty much their history.  
5 I don't believe they ever worked as a tourist sub. They were an  
6 acrylic hull, two-seat vehicle, a design that's very typical now,  
7 but they were quite radical in their time. They were the first of  
8 the kind of transparent bubble subs. They were designed by [REDACTED]  
9 [REDACTED], a name that you may be familiar with. And so they were  
10 considered fairly radical in their day.

11 A fairly simple design actually, and that design has been  
12 taken and used by let's say Triton -- or at least emulated, I  
13 should say, by Triton Subs. Most of their tourist and exploration  
14 subs follow that same acrylic bubble design; big battery system  
15 down below; strong riding moment, a very stiff boat that stays  
16 quite strongly vertical in the water. The arrangement of the  
17 thrusters is very similar in the Triton subs to the *Deep Rover*  
18 2's.

19 Q. Thanks. I want to talk a little bit -- before I get off of  
20 the subject of the construction, so what type of construction subs  
21 have you owned and/or operated in? And by construction I mean the  
22 hull, the pressure hull. So you mentioned acrylic. What other  
23 types of constructions have you been involved with?

24 A. Okay. So the *Mirs* had a steel hull. They used a high nickel  
25 maraging steel. They -- it was formed in two hemispheres which

1 were, I believe, bolted together as opposed to welded. And that  
2 was the Finnish -- from Finland. It was -- you know, they were  
3 built in Finland, at a yard in Finland. Obviously the acrylic  
4 subs, the -- with the [REDACTED] design, which were two acrylic  
5 hemispheres that were just joined by acrylic bonding, which is  
6 almost like welding because it's the same material.

7 The *Deepsea Challenger*, we looked at a lot of different  
8 potential pressure sphere materials. We looked at titanium. We  
9 eventually settled on -- we even looked at glass for a while. I  
10 know the Navy had done some work with glass under extreme  
11 pressure, but there were still too many variables on that. We  
12 went with a high ductile, high nickel steel called EN26, that was  
13 developed in the UK in the second world war for gun breech, you  
14 know, big guns, naval guns, design. And we did that primarily  
15 because of our timetable. Titanium would have set us back about a  
16 year to get the input slabs that we needed, so we went ahead with  
17 the EN26. And then we forged our own hemispheres and figured out  
18 how to, you know, weld them together and all that sort of thing.  
19 I mean, we were working with some pretty high level metallurgists  
20 and experts on that sort of thing in Australian.

21 I remember we had about a 6-month setback where our finite  
22 element analysis showed that the weld material that was proposed  
23 by Apollo Forge, the people that were actually doing the forging  
24 and construction, would have been in yield at our service depth.  
25 So we had to start over and figure out a different weld material

1 that would have worked and, you know, we went through very, very  
2 extensive stress field analysis in FEA to get the sphere very  
3 finely tuned to what it needed to be. We worked with a company in  
4 Tasmania called Finite Elements. A gentleman -- run by a guy  
5 named [REDACTED], who did all the computer sims.

6 We spent about 3 years on the sphere design before we  
7 actually built it. And we built the sphere first and then we  
8 pressure tested the sphere first before we went ahead with the  
9 rest of the construction of the sub because we knew it's all about  
10 the pressure boundary, as I'm sure you're learning about these  
11 vehicles. All of the -- all the externalities, all peripheral  
12 systems, you know, buoyancy, communications, all those things, are  
13 all secondary to, you know, having a safe -- a high, you know,  
14 what do you call it, margin of safety with that pressure boundary.

15 Q. Can you tell me a little bit more about the EN26 and the  
16 pressure tests that you put it through and what type of tests, you  
17 know -- what type of tests you used, if you did, you know,  
18 unmanned dives or whether you did pressure boundary testing or --  
19 you know, it can be ocean test facility and those types of things.

20 A. Yeah. The important thing to remember on the pressure  
21 boundary is that it doesn't consist just of the hull. It consists  
22 also of the penetrators, the hatch, and the viewports. So you  
23 have to think of it all as a system, anyplace that the pressure  
24 can be problematic. Implosion is the obvious problem. The thing  
25 that dumbfounds me about this, about this whole thing is implosion



1 should never be on your mind when you're in a sub. It should  
2 have -- that should have been eliminated as even the most remote  
3 possibility very early on in the engineering phase. Leakage at a  
4 penetrator could always become a problem. Hatch seating, viewport  
5 seating, if you're using an acrylic viewport as we did. You know,  
6 it has creep due to, you know, cold flow deformation and all those  
7 things have to be thought through.

8       So when we completed the sphere -- and by complete I mean the  
9 penetrators were installed and the acrylic viewport was installed  
10 so it was ready for actual pressure boundary testing, we shipped  
11 it to Penn State and we tested it in their 16,000 psi chamber at  
12 Penn State. Which means that it wasn't overpressure testing. The  
13 only place to do overpressure testing was in Russia, and I'd had  
14 enough dealings with the Russians to not want to send my sphere to  
15 Russia. Just there's a lot of payola and there's a lot of things  
16 involved that I didn't want to deal with.

17       So because we were not able to overpressure test the sphere,  
18 we came up with two protocols. One was that we covered it with 28  
19 strain gauges and we looked at the performance curves that we were  
20 able to achieve down to -- the 16,000 psi gets us to our service  
21 depth. It doesn't get us to an overpressure test. But we worked  
22 with the metallurgist and said, if you're curves agree all the way  
23 down to your test depth, then you can extrapolate those curves  
24 within the known -- because it's an isotropic material. You know,  
25 we're not dealing with a composite where you have to actually

1 eliminate failure. And the other thing we did was an unpiloted  
2 dive at full ocean depth. So when we finally got out to the  
3 Challenger Deep, we basically dropped the sub to the [REDACTED] on an  
4 [REDACTED] program, treated it essentially as an autonomous  
5 vehicle. And so we, you know, we got all the data that we needed  
6 from that as well.

7 The other thing is I have to point out with the *Deepsea*  
8 *Challenger* because classification is a big issue around this. The  
9 sub itself in its all-up configuration was not classified. It was  
10 considered an experimental vehicle. Myself and my co-designer  
11 were the only two people that were ever meant to pilot the  
12 vehicle. So we never had paying passengers. It was a solo, it  
13 was a solo -- a one-seater anyway. So, you know, we decided that  
14 we would use that as a pilot program and later we would ideally  
15 build a second sub that was a two-seater, at which point we'd go  
16 through full classification once we had proof of concept. So I'm  
17 very familiar with the classification process and we're very  
18 familiar with like why we didn't do it on that particular vehicle.

19 That said, we had a group called Bureau Veritas, who are --  
20 you probably know them --

21 Q. Yeah.

22 A. -- in Australia. Bureau Veritas were with us every step of  
23 the way in the design and qualification of the sphere. So we have  
24 a signed essentially classification of the sphere itself. What we  
25 don't have is classification of the all-up vehicle with all its

1 peripheral systems.

2 Q. Understood. And the overpressure test, do you know what  
3 percentage that would be of your rated dive depth?

4 A. It was 100 percent.

5 Q. 100 percent?

6 A. So 16,000 psi is essentially the pressure at full ocean  
7 depth.

8 Q. Um-hum.

9 A. And that's what the Penn State chamber could do.

10 Q. Okay. But the question -- so what would be considered the  
11 overpressure test? Would that be 125 percent or anything above --

12 A. Yeah. Yeah, you -- there's a -- overpressure testing is a  
13 bit controversial. I have my own opinions about it. I think it's  
14 a good thing to do up to but not including a yield threshold of  
15 the material itself. So if you're on a safety factor as we were  
16 of 1.65 or 1.7, then 125 percent would have been about the right  
17 number. You could go higher if you want -- I mean, I would say  
18 with any outboard implodable volumes on a vehicle, I would go to  
19 150 or 200 percent. I'd want to be absolutely certain that none  
20 of the small components around the vehicle could implode. Because  
21 obviously there's the danger of a sympathetic implosion, you know,  
22 and we've seen accidents like that happen on deep unpiloted  
23 vehicles.

24 LCDR [REDACTED] Mr. [REDACTED] if we can we take just one second  
25 real quick.

1 Mr. [REDACTED] we've been going for about 27 minutes now. Do  
2 you want to introduce yourself, sir? I apologize.

3 MR. [REDACTED] No, I apologize for being late.

4 Mr. [REDACTED] my name is [REDACTED] I'm the chair of the  
5 Coast Guard Marine Board of Investigation. And I appreciate your  
6 time and apologize for coming in -- arriving late this afternoon.  
7 Or morning for you. So thank you.

8 MR. [REDACTED] Yeah. Well, thank you. Yeah, it's morning  
9 where I am anyway. Yeah, well, we've used the time productively  
10 and obviously there's a recording, so anything that came out of it  
11 will be available.

12 MR. [REDACTED] Yes, sir. Thank you.

13 BY LCDR [REDACTED]

14 Q. Mr. [REDACTED] I'm going to continue on with the basic testing  
15 and creation of your vessel. So did you determine how many cycles  
16 you could take it to that depth or was there -- was it one cycle,  
17 two cycles?

18 A. The sphere, we believed, was good for many, many cycles, in  
19 the 500 range, something like that. Cycling was not our problem.  
20 It was corrosion, right, because the particular seal that we used  
21 was subject to saltwater corrosion. So it would've required  
22 complete disassembly and inspection and reassembly. We figured  
23 somewhere on the order of 20 to 25 dives would've been about our  
24 limit on that. We had an upper boundary condition on the acrylic  
25 viewport because of the extreme pressure that it was seeing and



1 the cold flow characteristics of the acrylic material. We put an  
2 upper boundary of 10 dives per viewport. We felt that the  
3 theoretical limit was somewhere around 100 cycles, but we just  
4 made extra viewports and brought them with us and we were prepared  
5 to change them out every 10 dives.

6 Q. And the viewport was rated to the max depth --

7 A. Yes. Correct.

8 Q. -- of the vehicle?

9 A. But again, the acrylic material is very interesting. It  
10 behaves different than almost anything else. It does have a, a  
11 kind of a cold flow characteristic within the conic thrust and  
12 seat of the dome port.

13 I forgot to mention that we did high pressure testing of the  
14 acrylic ports, where we tested them to essentially failure. And  
15 they failed at about about 2X of the operating pressure. We built  
16 a -- because they were small, we could put them into a smaller  
17 chamber that could go up to I think 35,000 psi or 30,000 psi,  
18 something like that. So we put two viewports back to back in a  
19 common titanium seat or steel seat, and then we externally  
20 pressured those until we started to see fracturing. And so, you  
21 know, they were extensively tested.

22 They were our own design. We worked with [REDACTED].  
23 That's probably a name you've run across. [REDACTED] wrote a  
24 book about this thick. He was the Navy's primary consultant on  
25 acrylic viewports for human-occupied vehicles. And he was

1 consulting with us up until his death, unfortunately, in the  
2 middle of our program. But he had already signed off on our  
3 design.

4 Q. And to build your -- I was going to call it a vehicle, if  
5 that's a proper terminology to call it.

6 A. Sure.

7 Q. So in creating and building and testing your vehicle, could  
8 you estimate the -- you gave us the time, but can you determine  
9 how much does it cost to actually go through all the proper  
10 testing to get a vehicle to that depth with that amount of cycles?

11 A. I'm not sure we ever broke it out as a separate sort of  
12 budget line item. It was so integrated into our day-to-day  
13 process. We had a 20,000 psi chamber. We had a 30,000 psi  
14 chamber. We had a number of chambers at our facility that we  
15 built ourselves. My colleague [REDACTED] was very good at  
16 designing and building pressure test pressure chambers. So we  
17 tested every component multiple times, every circuit board, every  
18 pressure vessel, the thrusters, everything. They were constantly,  
19 constantly running on chambers runs. It was an integrated part of  
20 our process. So we never broke it out and it wasn't really done  
21 by an external testing body. It was integrated into our in-house  
22 operations.

23 So I should loop back. We -- early on, we had an engineering  
24 sort of brainstorming session with the Woods Hole team, and I'm  
25 very close with them. You probably know [REDACTED], who runs

1 their engineering group. They were about to start building their  
2 Nereus vehicle, which was an unmanned ROV/AUV, hybrid mode vehicle  
3 for full ocean depth, at the same time we were starting our  
4 vehicle. So we kind of had a little symposium where we said,  
5 look, there may be components that can be shared in common, why  
6 don't we, you know, spend the non-recurring engineering costs  
7 jointly and then just make a number of units that can go on each  
8 vehicle. And we actually found out that we were too divergent in  
9 our engineering cultures.

10 They were going to use ceramic spheres for floatation and  
11 ceramic pressure vessels with airspaces inside and 1 atmosphere  
12 electronics. I said I'm not comfortable with that for a human-  
13 occupied vehicle when I'm the human because of the danger of  
14 sympathetic implosive failure of relatively small implodable  
15 volume outside the main crew pressure boundary could cause that  
16 crew sphere to fail if it implodes. We were very, very aware of  
17 this problem. There had been a lot of -- there's a lot in the  
18 literature around it. So they were determined to go their way. I  
19 said we're not going to do that, so we used a completely different  
20 system, which you -- I'm sure you've heard the term PBOF, pressure  
21 balanced oil filled. Our batteries, all of our electronics, all  
22 of our outboard systems were all at ambient pressure, meaning the  
23 electronics had to be vetted to be able to see that pressure of  
24 16,500 psi, which was the sort of design depth of -- full ocean  
25 depth in the Challenger Deep.

1        So we were pressure testing all day, every day. Every  
2 component that would populate a circuit board had to go through  
3 validation, multiple, multiple cycles, make sure it didn't fail,  
4 before we could even design a circuit board. And then I think  
5 there were over 1200 circuit boards on the vehicle, because there  
6 was a circuit board in every module of the -- or every small unit  
7 of the battery system. We called them battery boxes, and the  
8 boxes were grouped in modules, and the modules were on separate  
9 redundant buses. The whole vehicle was designed to be not failure  
10 proof but small outboard failures would not take down the overall  
11 operational capability of the vehicle. It was a high multiple  
12 redundancy system: multiple thrusters, multiple battery buses,  
13 etc., etc. So that's why we never really broke it out as a line  
14 item, that kind of testing.

15 Q. Understood. So thank you for that. I kind of want to back  
16 up -- not back up, but I want to discuss you working with class  
17 with a -- I don't want to call it a novel product with a pressure  
18 vessel, but a new type of construction, a new, using a new -- how  
19 did that work and how was it working with class? And I know you  
20 have a lot of experience with class. And you said it was BV you  
21 used?

22 A. Yeah, Bureau Veritas Australia.

23 Q. Yeah.

24 A. They were great. There was one person from BV that worked  
25 with us, I want to say for about 2 years; reviewed our FEAs, made



1 recommendations. He knew his pressure vessels. He knew internal  
2 pressure vessels and external pressure vessels. You know,  
3 pressure going two direction -- or in different directions is a  
4 whole different animal. I'm trying to remember his name. Right  
5 now it's escaping me. We worked with him, you know, 14, 15 years  
6 ago. He was with us, as I recall, for about 3 years. Through the  
7 final all-up testing, he flew with us to Penn State. That was  
8 in -- that would have been in September of '09 we did that  
9 testing. The sub didn't make its dives, its sea trials and its  
10 deep dives until February or March of 2012, but he was with us  
11 throughout the earlier stage of getting the sphere finished. And  
12 then they -- I don't have the certification with me, but they did  
13 certify the sphere.

14 I found it to be a good experience. I found his input  
15 welcome. I found it comforting, you know, as the person not only  
16 paying for the vehicle but the one that would be piloting, you  
17 know, to full ocean depth. We worked very, very closely together.  
18 He worked very, very closely with [REDACTED], obviously, because  
19 they're both Australian. But he made it -- I felt like he made it  
20 a project of personal interest, you know. And he brought a  
21 tremendous amount of experience in metallurgy and pressure vessel  
22 design to the situation.

23 And he alerted us to a problem that was a potential problem,  
24 which is that we used a material called 300M for the hatch, which  
25 had a microscopically different bulk modulus than the EN26 that we

1 used for the rest of the sphere.

2 Q. Yeah.

3 A. And he said there is a possibility that you might not be able  
4 to get the hatch open after -- you know, that the way that the two  
5 would interface under pressurization, that there could be a  
6 binding problem. And so we looked at ways that we could solve  
7 that by slightly changing the conic angle of the hatch. And he  
8 brought in the documentation for scenarios where he had seen that  
9 problem before. We incorporated it into our design, etc. etc.

10 So when we actually did our pressure testing, I think we did  
11 three pressurizations to 16,000 psi and we had no problems with  
12 anything with the penetrators or the viewport or the hatch itself,  
13 the functionality of the hatch. And we never had any problems  
14 with any of those things in operation.

15 Q. And did you -- I know you said that you used strain gauges  
16 throughout your testing. Did you use them throughout operation as  
17 well?

18 A. No. No.

19 Q. No. Okay. Have you ever used --

20 A. That's actually not a bad idea. It just -- it never occurred  
21 to us. We felt we were beyond that stage once we had the sphere  
22 certified. But it wouldn't have been a bad idea.

23 Q. Yeah. Understood. I appreciate that.

24 A. Just, you know, additional complexity. These vehicles get  
25 quite complex quite quickly in terms of all the electronics for

1 the instrumentation. Our vehicle's very, very different than  
2 something like the OceanGate vehicle. I mean, we had a lot of  
3 lights and very, very high capability in the battery system. We  
4 had a -- it was a 100 kilowatt design, which is quite a large  
5 battery for a relatively small sub, and, you know, lighting,  
6 camera, so many overlaid electronic systems, and comms,  
7 navigation. We had full redundancy in comms. We had backup  
8 beacons. We had all kinds of things on the sub. So there were  
9 many, many layers of electronics to the sub. I guess we figured  
10 the -- the strain gauge question never came up. That's -- I'm  
11 going to put that -- I'm going to write that one down.

12 Q. Okay. So, and then -- discussing that, so you had mentioned  
13 encyclic testing. Have you maintained the *Deepsea Challenger* to  
14 actually redo testing of the pressure hull and the systems?

15 A. The sub was donated after the expedition to Woods Hole, with  
16 the agreement that they wouldn't operate the sub but they would  
17 completely deconstruct it and they would incorporate the  
18 technology into some of their future programs, which they have  
19 done, and that any components that they could use from it, like  
20 cameras and lights and things like that, that they would  
21 cannibalize into their other vehicles.

22 Woods Hole had the same problem of it being a solo pilot, so  
23 they couldn't take a science observer. I mean, when I dove the  
24 sub, I was the pilot and the science observer and the imaging guy  
25 and all of that, all at one. It was like a, you know, one-man

1 band. And so it didn't fit the way they organized their program,  
2 so the donation was made so that they would publish the technology  
3 and incorporate the technology into their future programs.

4 So no, the sub has not been maintained in that way. There is  
5 the possibility that we could take the sub out of it -- it's  
6 basically intact, it's just dormant. It's been reassembled and  
7 not tested but switched on, so we know that it works. It's  
8 currently going to be in a touring exhibit. We could bring the  
9 sub back to life at some point and use it programmatically, at  
10 which point I think it would be a good thing to class it just to  
11 have done that. You know, once again, solo pilot, but at a  
12 certain point we want to train other pilots so that we got more  
13 capability out of the vehicle. We just never got that far with  
14 it.

15 What we found was that there -- we were expecting some  
16 program money from, you know, from science and academia to go to  
17 what I always called Phase 2. Phase 2 we go sort of operational  
18 on a multi-year basis. It turns out there's not a lot of interest  
19 in academia for human-occupied vehicles at those depths, at hadal  
20 depths. They get more bang for their buck with robotic vehicles  
21 and AUVs and things like that. There's not much money in --

22 Q. You had mentioned --

23 A. There's not much money in it in general. That's the problem  
24 for deep ocean research.

25 Q. You had mentioned pilot training. And you kind of got your

1 pilot training through the Russian *Mir* subs. Is there --

2 A. Informal, yeah. Yeah.

3 Q. Informal, yeah.

4 A. We did a very, very carefully worked out pilot training  
5 program for the *Deepsea Challenger* where we built a 100 percent  
6 mock-up of the vehicle with all internal electronics, life support  
7 and everything. And we did actual lock-in dives in a freezer,  
8 where -- you know, just like kind of a NASA plugs-out test, you  
9 know. You'd sit in the vehicle and you'd make a simulated 12-hour  
10 dive. You'd cold soak. You'd change your, you know, clothing,  
11 etc., according to the checklist. You'd run through all systems  
12 over and over. They'd throw simulated emergencies at you from a  
13 control room. I mean, we did it exactly the way NASA would do it.  
14 I don't know how many other sub operators do it that way, but we  
15 did it that way because we felt it was important. And I wanted  
16 the very best training that I could have to operate the vehicle.

17 So we -- you know, we had a manual this thick. It was  
18 developed by a guy named [REDACTED] in Australia. He was a cave  
19 diving instructor, so he knew -- he basically knew rebreather  
20 systems intimately. We built our own -- we designed and built our  
21 own life support system. Basically we were kind of arrogant,  
22 which is we didn't like the standards for a lot of what's out  
23 there so we kind of set our own higher bar in a lot of areas.  
24 Because, you know, personally what scared me in a sub was not  
25 implosion, we had designed against that, it was fire. You're in a



1 very small volume. You've got a lot of electronics packed in  
2 there. If you have a fire, it can contaminate your breathable air  
3 very, very rapidly. So we had a 100 percent redundant backup  
4 system that we could go on with a full-face breathing mask, very  
5 much like you do -- you know, an SCBA-type mask. And we could  
6 literally switch over to a fully redundant system. No other sub,  
7 to my knowledge, has that. They usually have a BIB system, built-  
8 in breathing system, but nothing like what we designed.

9 Q. And with that manual, the operations manual, would you guys  
10 run your own types of -- we call them like BECCes in the Coast  
11 Guard. So would you run like engineering casualty control drills  
12 and have those --

13 A. Absolutely.

14 Q. -- things that you would set up and kind of run through them?

15 A. Absolutely.

16 Q. And how would that work?

17 A. [REDACTED], who designed the system and designed the  
18 training mock-up and the, you know, the cold soak room and the  
19 control room for it, he ran vigorous tests. He actually did a lot  
20 of the pilot runs himself. His maximum run, I think, was 18  
21 hours, which was kind of a -- the sub was not designed to dive for  
22 18 hours, but that was -- if you had a contingency scenario where  
23 you were stuck on the [REDACTED] and you are waiting for a redundant  
24 weight-drop system to time out. Because ultimately if you -- the  
25 way we designed the vehicle was we had a -- we had manual ballast

1 drop. If that failed because of some communications error from  
2 the inside to the outside of the vehicle, then there was a timer-  
3 based system, and then there was even a simple corrodible link  
4 system that would fail chemically. And the outside time from the  
5 time of the start of the dive in saltwater was somewhere between  
6 18 and 22 hours. So he did a -- like a worst-case contingency  
7 dive, where, you know, he basically locked in for 18 hours. I  
8 didn't have to do that. My longest training dive was 12 hours.  
9 But he was just exploring the outer boundary essentially of what  
10 our contingency protocols were. And he and I sat and brainstormed  
11 this stuff, but he was the one that actually designed it and wrote  
12 it all up, created the training protocols.

13 And another thing that was unusual about our operation is  
14 everybody who designed and built the sub went with the sub to sea  
15 for the sea trials, even though some of these engineers had never  
16 been a ship before. I think the most dangerous part of our whole  
17 operation was these young software engineers puking over the  
18 railing in a high sea. But I wanted them with me because I knew  
19 as an experimental vehicle we would be finding little flaws and  
20 ways to improve it and so on as we went along. We wanted to  
21 emerge out of that sea trial program with a fully vetted and  
22 refined vehicle before it went into Phase 2. We never went into  
23 Phase 2, but that was our game plan.

24 Q. You mentioned the drop weights. So did you guys utilize a  
25 motorized system as well as a hydraulic release or was it just the

1 hydraulic release and then the squibs or the sacrificial anodes  
2 that would dissolve to therefore drop the weights?

3 A. So there was a, there was sort of a series that -- so the  
4 prime system was based on a simple breakable electric circuit.  
5 And I said, guys, I don't want this going through the computer.  
6 Because we had a PAC, a P-A-C, on board, programmable controller  
7 for all the subsystems so that we could limit the number of  
8 conductors going through the penetrator. We had an electronic  
9 penetrator -- an electrical penetrator and we had a fiber optic  
10 penetrator. The fiber optic penetrator was its own dedicated  
11 thing. We only had a limited number of conductors on the  
12 electrical penetrator.

13 And they said, well, we don't want a dedicated circuit for  
14 the weight drop because it'll limit how much we can MUX over  
15 the -- you know, multiplex over the other conductors. I said I  
16 don't care; we're not going through the PAC. The PAC can latch  
17 up, the PAC can glitch, the PAC can go down, and then I lose  
18 control of my ballast system. I said I want it medieval. I want  
19 it dead simple: I throw a switch, breaks a circuit, a magnet  
20 releases, an electromagnet that had its own dedicated battery  
21 releases. So the sort of hierarchy was commandable release, I  
22 break the circuit with a toggle switch, just dead simple.  
23 Everything else was very sophisticated electronically on the  
24 vehicle. I said I wanted that medieval. So I throw the switch,  
25 the electromagnet releases, and through a kind of mechanical

1 advantage it then releases the weights.

2       There were two separate drop weights on two separate slides  
3 on either side of the vehicle. They were tested over and over and  
4 over, like hundreds of cycles in a pressure chamber at  
5 temperature. I said this is the one thing that absolutely  
6 electromechanically cannot fail on the vehicle. So I had 100  
7 percent -- I actually helped design the mechanical interface with  
8 the guys who built that. They were an outside contractor that we  
9 got in, people that I had worked with for 30 years. I knew them  
10 very well. And they were more paranoid than I was. But paranoia  
11 is a healthy thing when you're designing a submersible vehicle.

12       So that was the first step in the hierarchy. If that failed  
13 for whatever reason -- we couldn't imagine a reason why it would  
14 fail -- then the dedicated electromagnet battery would just run  
15 down. And we did a lot of testing to know like how long it would  
16 take to run down. And we always set it at somewhere around 14, 15  
17 hours so that it wouldn't suddenly interrupt us in the middle of  
18 an operation at hour 11 or 12 on a dive, which could be dangerous  
19 in and of itself.

20       And then if that failed for whatever reason we couldn't  
21 imagine, there were -- like let's say there was a mechanical  
22 failure, something fouled the mechanism, something got into the  
23 mechanism and fouled it or something broke and fouled it, the  
24 entire weight drop slide unit itself, the actual -- the base unit,  
25 so that the weights would slide off, the base unit was attached to

1 the sub by two frangibolts. And so the frangibolts would then --  
2 could then be commanded. So if I commanded the weight to drop and  
3 it didn't drop, I'd then go to the frangibolt. It takes them a  
4 minute or so to heat up and then break the bolts, and then at that  
5 point we lose the entire system, but that's preferable to -- so  
6 there was no hydraulic amputation. We used the frangibolts as the  
7 amputation system. Because when we were originally designing the  
8 vehicle, we didn't really want hydraulics. It was a layer of --  
9 we eventually wound up with a hydraulic manipulator and a few  
10 other hydraulic functions on the sub, but initially we tried to do  
11 everything with kind of solid state electrical solutions.

12 If you got past the frangibolts and that didn't work, then  
13 there was the sacrificial anode, you know, corrodible link which  
14 would fail. So, you know, I guess that's quadruple redundancy,  
15 something like that.

16 Q. Yes.

17 A. Yeah. So -- and, you know, we had the same frangibolt system  
18 on the manipulator as well. So if -- you know, obviously  
19 manipulator fouling is always a risk with submersibles. To my  
20 knowledge it's never actually happened in a way that required  
21 outside interdiction, but I know there are stories across the last  
22 50 years of sub ops where people had to drop their manip.

23 Q. Um-hum. Now did you also have a variable ballast system for  
24 external -- for ballasting, for like external high pressure air to  
25 be able to put it into, say, like an umbrella type system or



1 whatnot to use air for ascent?

2 A. Yeah. We didn't begin the -- we used essentially an external  
3 ballast system where we had a lift bag, and then we'd physically  
4 release the lift bag to start the descent. So we started the dive  
5 negative. We didn't have space inside the vehicle for a variable  
6 ballast system. But what we did do is we had a passive variable  
7 ballast system that would deploy on a set. So basically it would  
8 pressurize at -- a very large bright orange lift bag would emerge  
9 at about 1,000 feet. And that way, if we were -- if we had some  
10 sort of compromised buoyancy, some piece of syntactic had crushed  
11 or broken off or, you know, anything that compromised our ability  
12 to surface, we had an additional, I think it was, 8- or 900 pounds  
13 of buoyancy at that point, and a very high visibility flotation,  
14 you know, system.

15 So typically we would surface about 300 or 400 pounds buoyant  
16 just innately in the structure of the sub, and then we had an  
17 additional 8- or 900 pounds of gas, so variable buoyancy. But it  
18 was a passive system. It armed on the way down due to pressure  
19 and it released on the way up due to pressure. It was a fairly  
20 clever design, I think actually. Because the problem is what's  
21 your gas source? Any gas cylinder that you put on the vehicle  
22 becomes an implodable volume at full ocean depth. Even if it's  
23 pressurized at 10,000 psi, it's still 6,000 psi additional  
24 external overpressure on top of that. So there was no gas bottle  
25 in the world that could do that.

1        So we designed a gas-over-oil system so that the gas went  
2 into solution in an oil that came into the cylinder and then came  
3 back out of solution and pushed the oil out and then continued to  
4 expand into the lift bag. It was a very clever system. I don't  
5 know anybody else that ever did something like that, but -- that's  
6 part of what we turned over to Woods Hole, if they ever found a  
7 purpose for any of these things. Because there were -- I would  
8 say there were about 15 or 16 highly innovative things on our  
9 vehicle that were kind of unprecedented.

10 Q. Absolutely. I'm just going to ask you about a few more  
11 things before I take it over to Mr. [REDACTED] and Mr. [REDACTED] real  
12 quickly. So I believe when you were talking about the *Rover 2*, it  
13 had a dedicated support vessel. Was that with (indiscernible)? I  
14 apologize (indiscernible) --

15 A. No. It was *Mirs*. The *Mirs* had a dedicated support vessel, a  
16 dedicated handling system. The *Deep Rovers*, when we got them, we  
17 didn't get a vessel, we just got -- we got all of the support  
18 systems, but not the ship.

19 Q. Understood.

20 A. And so we would use a ship of opportunity.

21 Q. What did you use for the *Deepsea Challenger*?

22 A. *Deepsea Challenger*, we used a -- it was a, basically an oil  
23 company or an oil support ship that was a wet deck, a wet deck  
24 ship, like a typical pipeline inspection or oil rig support ship.  
25 It was called the *Mermaid Sapphire*. It was operated by Sapphire

1 Marine out of Singapore. And they did a lot of work in southeast  
2 Asia and the western Pacific in -- for, you know, oil contracts.  
3 Q. And with the vessel, what was your expectation of the vessel  
4 as like a support ship? What did you look for? I mean, I'm going  
5 to guess that you were part of the contracting and setting up.

6 A. Sure.

7 Q. What were some of your requirements for the vessel?

8 A. We wanted DP2. We wanted sub tracking. We wanted an onboard  
9 ROV so that we had safety backup and support down to whatever  
10 depth. Theirs was only good to 1500 meters, but we knew as long  
11 as we were diving in less than 1500 meters in our trials, we had a  
12 backup vehicle.

13 And just as an aside in case I forget to say it later, I  
14 think one of the recommendations you should strongly consider is  
15 the idea that anybody operating a human-occupied vehicle for deep  
16 exploration should have an ROV, at least an observer class ROV if  
17 not a work class ROV, on board that can make the depth. Because  
18 if you think about the tens, hundreds of millions of dollars spent  
19 by people to go determine what we all already knew, which is that  
20 it was lying at its -- that the *Titan* was lying at its last known  
21 position on the [REDACTED] and it wasn't a rescue, it was a recovery,  
22 you know, that -- I think the capability to determine that a  
23 rescue is required should be innate on the vehicle. If you can  
24 afford a human-occupied sub and a support ship of that class,  
25 which is going to cost you a million bucks a week, you can afford

1 a small fiber-spooling ROV that can make the depth and get eyes  
2 on. That's just my recommendation.

3 Q. Thank you, sir, for that. Appreciate that.

4 A. But anyway, in terms of support vessel, we wanted DP2, we  
5 wanted an onboard ROV, we wanted -- so that we had some backup  
6 down to -- we knew we were going to be going far beyond the ROV's  
7 depth and that I'd, you know, I'd be solo beyond that, but -- and  
8 my requirements were both for safety and for imaging. We could  
9 image from the ROV, we could image the ROV from us, but we  
10 interested in imaging our sub in operation so we could study its  
11 performance. So we were -- you know, we wanted a crew that seemed  
12 capable of doing things that they weren't used to.

13 And so we spent a lot of time with the Sapphire company  
14 figuring out who they were going to populate their key, their top  
15 crew members with, the captain and so on. Had they done sub ops,  
16 had they done -- obviously they've got an onboard ROV, they've  
17 done a lot of ROV ops. They had sub following, so they had they  
18 tracking capability to follow their own vehicle. They had -- we  
19 were able to get onto their frequency with our transponders so  
20 that they could track our vehicle as well.

21 Now if you know sub ops, DP2 and UQC comms are not very  
22 compatible. When you're operating the DP thrusters, they often  
23 contaminate the water with too much sound and make your voice  
24 communications difficult. So we had to have somebody that could  
25 operate in DP but switch out of DP for comms and have a pretty

1 disciplined protocol around that. I mean, we learned how -- the  
2 Russians do it without DP. What they do is they motor up weather  
3 and then they drift down across the dive site for an hour so that  
4 they have clear comms. Then they switch comms to a small boat and  
5 they motor back up weather and they hand off and so they have an  
6 unbroken comm cycle. And we adopted that same methodology, except  
7 when we were doing joint ops with the ROV, in which case we had to  
8 have a more of a compromised system. But we brought that to the  
9 *Mermaid Sapphire* captain, said this is how we'd like to operate so  
10 that we have an unbroken comm cycle. And it worked very well.  
11 You know, we know had one comms transducer on a 10-meter rib and  
12 we had another one hanging from the ship. And so they'd just hand  
13 off.

14 Q. And by comms, you're not talking verbal communications, more  
15 as --

16 A. Oh, yeah. Sure.

17 Q. -- (indiscernible)

18 A. Oh, we had voice comms all the way down. We had voice comms  
19 at 7 miles down. Yeah. I talked to my wife.

20 Q. Like what (indiscernible) --

21 A. When I reached depth --

22 Q. -- system?

23 A. When I reached depth, I reported in. I gave the -- you know,  
24 I gave the depth. I said I'm on the [REDACTED] depth is, you know,  
25 whatever. And there was a long pause and then the next voice -- I



1 heard "copy" from the comms guy, and then the next voice I heard  
2 was my wife saying, honey, congratulations, you know.

3 Q. Well, that's -- I didn't know that was even possible. That's  
4 fantastic. I know a lot of the new systems are using like the  
5 acoustic telemetry modem to send up texts back and forth, but I  
6 didn't know actually verbal was a possibility.

7 A. Yeah. We had a text backup. You know, there was obviously  
8 lower bandwidth. If we failed in voice, then we'd switch to text.  
9 But I never had to. I mean, we spent a lot of time at sea doing  
10 at sea test operations in the Tasmin Sea off Sydney getting all of  
11 our launch recovery and our deep comms and so on worked out before  
12 we even went off on our sea trials.

13 Q. And did you ever lose communications or tracking at all  
14 throughout your process?

15 A. Our system was not designed to have accurate tracking beyond  
16 a certain depth. They could only get us to, I think, 4,000 meters  
17 with their system on board the ship. And then beyond that, we had  
18 to do old-fashioned plotting. Right? So we basically used  
19 multiple transducer positions and we'd take readings and then a  
20 very, very capable guy named [REDACTED] would literally plot it on  
21 a -- like, you know, with a pencil. But they were pretty  
22 accurate.

23 Q. Just one more question. So your -- the *Deepsea Challenger*,  
24 when it was on the aft portion of the vessel, for it to get into  
25 the water was it an A frame, was it a davit lift in? Like how

1 were you then put into the water?

2 A. We used a less than optimal system. I had designed a  
3 dedicated system that would have gone on the -- would have welded  
4 onto the back of the ship, but we ran out of time to build it. We  
5 were assured by the Sapphire guys that they could do it with their  
6 crane. Turned out they were kind of full of shit. So we -- when  
7 we were in Sydney, what I did was I built a mock-up of the sub  
8 that was the full weight and exact configuration and we did  
9 repeated trials at sea in parallel with finishing the build of the  
10 sub to launch and recover what we called the mock-up sub or the  
11 dummy sub. And what we wound up with was something that we had  
12 used with the *Deep Rovers*.

13 When you have a pendulous load under a crane, if you don't --  
14 if you have a snubbing system like the Russians did or like we'd  
15 used on other ships, then you can snub the sub, have control of  
16 it, put it in the water, and then release it. We didn't have  
17 that, so it was essentially a pendulous mass on a cable, which is  
18 not desirable with an 11-ton sub. So what we did, we set up a  
19 lateral, a side bridle on it, which was a wide bridle, was made  
20 out of Dyneema, you know, straps sort of this big. It had -- I  
21 don't know, it was like a 10X safety factor or something. And we  
22 had a dedicated winch on deck that would laterally load the sub.  
23 And so the crane would swing outboard always farther than the sub.  
24 So the sub was essentially locked to the ship by gravity at an  
25 angle and the crane would swing out and then we'd lower the sub

1 and pay out the side loading winch. And we got pretty good with  
2 that by using the dummy sub.

3 So I went out and supervised the launch/recovery operations  
4 for about 2 months to get us dialed in on how to operate this.  
5 And then we operated it successfully. Because I knew that was  
6 going to be ultimately the dummy in the real sub and, frankly,  
7 launch/recovery operations always scare me more than the actual  
8 at-depth operations.

9 Q. Wow. Thank you, sir.

10 LCDR [REDACTED] I'm going to pause my questions for now.

11 Mr. [REDACTED] I can defer to you for any questions. You're  
12 muted, sir.

13 MR. [REDACTED] Yeah, why don't go to the NTSB?

14 [REDACTED] do you have any questions?

15 BY MR. [REDACTED]

16 Q. I really just have one. And I heard you say earlier that you  
17 didn't like the standards and I think -- at the time I think you  
18 were referring to back when you first started with *Mir*. So the  
19 thing I'm struggling with is, you know, are the standards adequate  
20 and people are just following them in our case or do we need to  
21 revisit the standards and, if so, which ones? Do you have a  
22 favorite class? You mentioned GL, DNV, ABS.

23 A. Yeah. I want to qualify that as specifically around the idea  
24 of diving to full ocean depth --

25 Q. Okay.

1 A. -- and that particular exotic regime. I think the standards  
2 that are in place now -- now I want to say upfront for  
3 transparency, I'm a minor equity owner in Triton. So I know --  
4 I've known [REDACTED] for 25 years. I'm a very small -- I  
5 think I've got like 5 percent of the company, something like that.  
6 So I'm very familiar with their operations, their standards, their  
7 safety manuals and all that sort of thing, and I've reviewed  
8 everything with them.

9 I think the actual standards that are applied to exploration  
10 vehicles in the less than 6,000 meter depth, right -- so you're  
11 talking 97 percent of the ocean floor and obviously all the  
12 tourist subs, I think the safety standards are very high both in  
13 terms of construction, classing, and operationally. And speaking  
14 for -- as a representative of Triton, there have been no incidents  
15 that required external assistance. And we never had an incident  
16 that required external assistance with the *Mir* program or with our  
17 own *Deep Rover* program or with our *Deepsea Challenger* program.

18 I think the standards are good. I think there's nobody  
19 really enforcing the standards, I think may be an issue. I mean,  
20 Triton knows that its ability to operate commercially is based on  
21 its safety record, which is 100 percent right now. It can't fall  
22 below 100 percent. It's just not allowable. So it's a mentality.

23 What I was talking about with respect to *Deepsea Challenger*  
24 was that, you know, some of the ways that things were done we felt  
25 that the specific challenge of what we were doing, the specific

1 mass constraints that we had and the specific operational  
2 challenge of a solo operation, that we needed to go beyond. We  
3 had to have a mentality of going beyond. Okay. That's what  
4 everybody -- that's worked for everybody else, we want to go  
5 beyond. That was just a, a kind of a mantra.

6 Q. Okay. How about for the surface tender or the mothership?  
7 Is there -- the standards you mentioned like they should have  
8 ROVs, what -- I know what you're looking for, but there's no  
9 requirements that I know of. I think the British have some for  
10 their flag ships, but that's about it. Is there something, is  
11 there -- are those standards adequate?

12 A. Well, I've never -- I mean, look, I always find that the ABS  
13 standards when I've been on various ships and we're brought in and  
14 we're given the safety brief and the lifeboat drills and the fire  
15 drills and all that, I've always found that to be adequate, but  
16 I'm definitely not an expert in that. And, you know, I've never  
17 been involved in having paying passengers going on any of our deep  
18 submergence vehicles. So this is an area where if you haven't  
19 talked to [REDACTED], I strongly recommend it. He's the -- he  
20 has designed more subs and, by a factor of at least 10, more  
21 humans have spent time in his subs than any other provider. He  
22 reckons that somewhere around 1.2 million human submerged hours in  
23 his vehicles. Now that includes your kind of 40-place, big, you  
24 know, 100-foot depth tourist buses, which is, you know, probably  
25 the larger part of that number.



1 Q. Sure. Sure.

2 A. But that's still an impressive figure, with 100 percent  
3 safety, no injuries or casualties. So I would strongly  
4 recommend -- he can talk about classing and operational safety  
5 standards and engineering safety standards a lot more than I can.

6 Q. Okay. How about safety management systems? So some of those  
7 vessels you're using have -- are required to have safety  
8 management systems, others don't, like the research vessels, so --

9 A. Right.

10 Q. Did you merge your safety system with theirs or were they  
11 just -- the ship's crew just a separate entity, just, you know,  
12 hands on deck helping you?

13 A. I think there was a -- if you think of it as a Venn diagram,  
14 you know, there was definitely an intersection set where we had to  
15 work together to create safe operating protocols. So I brought to  
16 that and other members of my team brought to that their experience  
17 working on different ships, some dedicated, some ships of  
18 opportunity. And this particular ship, the *Mermaid Sapphire*, had  
19 no prior experience with a human-occupied vehicle, plenty of  
20 experience with a remotely operated vehicle. So they -- so we had  
21 to create a set of operational procedures that everybody was  
22 comfortable with.

23 Q. Okay.

24 A. And of course, we have to defer to the captain always, you  
25 know, as the master. And if the captain ever saw anything he felt

1 was unsafe on his ship, we deferred to that. So we came to it by  
2 consensus, I would say. On a dedicated ship like when I was  
3 working with the Russians, that was just -- it was a work of art  
4 to behold how they did it.

5 Q. Okay.

6 A. And so, you know, and that -- but they had worked together as  
7 a group for 20 years, same ship, same submersibles, same handling  
8 system. So, you know, there was an awful lot to be learned there.

9 Q. Okay. Well, thank you for that. And my last question --  
10 I've asked this of everybody without -- it's a different topic  
11 really. Do you know where [REDACTED] carbon-fiber submarine  
12 is?

13 A. [REDACTED] deep sub, the --

14 Q. He started building --

15 A. Are you asking where --

16 Q. -- a carbon fiber. Nobody seems to know where it is.

17 A. I don't know, I don't know where it is. I mean, it was --  
18 there was a time when we were sort of in a friendly competition to  
19 get to the Challenger Deep first with -- [REDACTED] was dead by that  
20 point and it was now being funded by [REDACTED] and run by  
21 another guy. I never liked the [REDACTED] sub. I told [REDACTED]  
22 he was going to die in it if he dove it to the Challenger Deep. I  
23 told the -- I'm going up on his name right now -- the fellow that  
24 was going to dive it. I said it's a wound carbon-fiber cylinder,  
25 it's not going to work.

1 Now I never talked to Stockton Rush about that. He never  
2 asked me. I knew him socially, but I never got into the details.  
3 But I never liked the wound carbon-fiber concept. It's an amazing  
4 material for aerospace; in compression, bad idea.

5 Q. No, no, our understanding is (indiscernible) --

6 A. I'm sure going to -- you'll --

7 Q. -- originally, but --

8 A. -- you'll come to your conclusions around that, but we -- I  
9 mean, there's a, you know, group of people in the deep submergence  
10 community that sort of knew when they heard the news what had  
11 happened.

12 MR. [REDACTED] Okay. All right. Well, thank you for your time,  
13 sir. I appreciate that.

14 MR. [REDACTED] Yeah. Thanks for your question.

15 MR. [REDACTED] [REDACTED]

16 MR. [REDACTED] Yes, sir.

17 BY MR. [REDACTED]

18 Q. Thanks again, Mr. [REDACTED] I just had a couple follow-up  
19 questions. I'd like to know more about that *Mir* operation. I  
20 haven't -- don't know, you know, a lot of details, but  
21 first -- what was the occupancy of that -- of those submersibles  
22 in that time?

23 A. I'm sorry. The speed?

24 Q. Oh, I'm sorry, the max human occupancy? Was it up to  
25 (indiscernible) --

1 A. Oh, sorry. Three people. Right? So the typical -- I first  
2 worked with the *Mir* team in '95 and then subsequently in 2001, and  
3 then in 2005 -- sorry, 2003 and 2005. We had programs in each one  
4 of those years. And I think you weren't on the call yet, but I've  
5 made over 50 dives in that vehicle.

6 When we first came to it, their standard operational  
7 procedure was they had a pilot and an engineer and an observer,  
8 typically a scientist, marine biologist or marine geologist. We  
9 convinced them to go with two observers, and then that became  
10 their standard operating procedure after that. And I convinced  
11 them to do that by taking over certain of the engineer's duties  
12 around ballast control and sonar navigation just because it seemed  
13 like a fun thing to do. And they were fine. I mean, the Russians  
14 were simultaneously incredibly disciplined and also flexible  
15 thinkers. So we found them actually very easy to work with and we  
16 approached engineering problems together.

17 So they had a dedicated ship called the *Akademik Mstislav*  
18 *Keldysh*, is actually the name of the ship. And it was about 420  
19 feet overall. It had -- it operated the subs out of the starboard  
20 side. It was a dedicated hangar bay, two large clamshell hangars  
21 that opened like that. There was a central crane that could pivot  
22 and pick up *Mir* 2, pivot the other way and pick up *Mir* 1. It was  
23 a snubbing system where they pull it up into a capture mechanism.  
24 They'd turn the sub outboard, and then they -- there was a rack  
25 and pinion or like a crown gear that would rotate it and put the

1 sub in the water in the right configuration. So it was an  
2 excellent system. And then it released at the surface of the  
3 water. So you weren't hanging, you know, pendulously on a cable  
4 the way you would be even with an A frame.

5       Everybody thinks the A frame is best, but it's not. Any kind  
6 of a snubbing system is much better. Which is not to say that  
7 it's not still challenging getting the sub back into that system  
8 when you're at a high sea state. I think the highest sea state I  
9 saw them recover in was 20 feet. That's no fun. Made a nice shot  
10 in the film, but it was no fun.

11       Once again, they were -- this was operating back in the mid  
12 '90s, so the weather forecasting wasn't as good then as it is now.  
13 There's no excuse to get into that kind of sea state now. You  
14 just don't go. You just don't launch if you see a front or winds  
15 or whatever. There's really no excuse for any kind of accident  
16 now. I mean, we -- collectively, the community knows enough. And  
17 the community knew that OceanGate were breaking a lot of rules.

18       You know, I'd just like to contextualize something. I  
19 described the *Deepsea Challenger* as an experimental vehicle, which  
20 it is. Where we didn't play fast and loose with innovation was  
21 that pressure hull. That pressure hull was tried and true old  
22 school technology. We used all the existing literature to, you  
23 know, set our safety -- decide on our material, design it, inputs  
24 to the FEA. And, you know, the end result and the whole testing  
25 regime were all entirely conventional, which is why were able to



1 class the sphere. There are a lot of radical things about the  
2 configuration of the sub and a lot of the outboard systems, but  
3 none of those were really life threatening. They would only have  
4 impacted our operational capability and required us to abort the  
5 dive and make repairs. So we were really conventional when it  
6 came to the pressure boundary and we were -- we let all of our  
7 innovation be in other areas.

8 Q. Yes, sir. Do you happen to remember was the vessel that you  
9 mentioned, the (indiscernible) the vessel, is that Russian  
10 flagged? Do you know?

11 A. Is it Russian flagged? I believe it is, yeah. It's owned  
12 by -- I think it's not even being used for submersible operations  
13 anymore. They're using it, I think, in oil and gas. I've sort of  
14 lost track of it. But it was -- I'm pretty sure it was Russian  
15 flagged, yeah. It was owned by the Russian Academy of Sciences.  
16 I think at one point it was a spy ship, honestly, before it was  
17 converted to submersible operations. Because there was a big  
18 electronics bay down on deck 2 that we took over and turned into a  
19 TV station. It had a lot of old stuff in it that we couldn't even  
20 figure out what it was. That's pretty common knowledge. I don't  
21 think I'm spilling any beans here.

22 Q. Do you happen to know if those submersibles ever operated  
23 independently of the vessel or were they kind of part of the  
24 vessel itself?

25 A. It did. In the subs later years, the Academy of Sciences had

1 to -- they basically ran out of money. So the *Mir* team  
2 transshipped and they took the subs by truck to Lake Baikal and  
3 they dived them off a barge in Lake Baikal for a couple of years,  
4 which is a really interesting science subject, but they never went  
5 to sea again after that. So that's the only time I know of that  
6 those subs were not operated from the *Keldysh*. Because that whole  
7 thing was conceived as one integrated system.

8 Q. Yes. I was just curious if those submersibles were  
9 independently registered or flagged. You probably wouldn't  
10 remember that part.

11 A. I think that there was a discussion at one point about us  
12 chartering the subs on a long-term charter from the Academy of  
13 Sciences and putting them on a different ship and training up an  
14 international crew or a US-based crew to operate the *Mirs*. That  
15 sounded like it would have been possible to do, at least in the  
16 climate at that time, and this is going back 15 years or so. We  
17 just never did it. We were never able to get the funding to do  
18 that.

19 Q. Okay. Thank you. I think you already mentioned it, but all  
20 the times you were down, you know, on the *Mirs*, on your *Deepsea*  
21 *Challenger*, you never had a near miss even during like recovery  
22 operations or, you know, aloft in the (indiscernible) system even  
23 in a sea state potentially? I'm just trying to --

24 A. Yeah. Sure. So in terms of safety, we did a lot of  
25 operations around hydrothermal vents and we did a lot of

1 operations around deep ship wrecks, including the *Bismarck* at  
2 16,000 feet, *Titanic* at 12,500 feet. And you obviously have a lot  
3 of fouling hazards. I found that having two submersibles on  
4 station at the same time was a great comfort and a great  
5 redundancy. We never actually had an entrapment where we had to  
6 have the other submersible intervene. I recall having one  
7 scenario where we weren't sure if we were stuck or not and the  
8 other sub came over, took a look, and said, no, you're fine, just  
9 do this. That was a big help, you know, when you're 12,000 feet  
10 down.

11 I strongly recommend two vehicle systems where that's  
12 possible. Most people can't afford it. It was standard for the  
13 Russians. If I were going to develop a human-occupied vehicle  
14 system from scratch for myself to use, two subs.

15 Q. Yes, sir.

16 A. Then your rescue capability is innately right there.

17 Q. Yeah. Yes, sir. That's kind of why I asked the question. I  
18 appreciate the -- you know, recalling that, at least where you  
19 thought it might have been entrapment. It sounds like --

20 A. Yeah.

21 Q. -- because you thought it (indiscernible) --

22 A. I would think the descending of order of desirability would  
23 be, the highest sort of Cadillac level is you've got two equally  
24 capable subs. They're either on station at the same time or one  
25 has had to go back early, and then your worst-case scenario is

1 you're trapped for the length of time it takes them to recharge  
2 and come back down, which is not a big problem. Right?

3 Your next tier is you've got a human-occupied vehicle and a  
4 remotely operated vehicle operating from the same ship at the same  
5 time and if you need eyes on or you need some kind of assistance,  
6 the ROV can be deployed. I think your third tier, which would be  
7 the absolute minimum I would go with in the future is you've got  
8 your human-occupied vehicle and you've got an observer ROV, which  
9 can be quite a bit smaller, maybe a spooling fiber vehicle that  
10 can just be sent down to assess the situation and make  
11 recommendations and call for external assistance if necessary. I  
12 would not go below that tertiary level in the future personally.

13 Q. Yes, sir. Excellent. I only have a couple more questions.  
14 One thing I was wondering is during all your excursions to the  
15 [REDACTED] to the *Titanic*, was it always -- or even a thermal vent,  
16 was it always that case that you would charter the entire  
17 submersible? Was there ever a situation where you have other  
18 passengers or other I guess in this case observers who were paying  
19 separately?

20 A. Yeah. In my first expedition we chartered the whole *Mir*  
21 operations, the *Keldysh* and everything, we did it ourselves  
22 directly. Subsequently -- and then after that, a gentleman that I  
23 had mentioned before you joined the call named [REDACTED] out  
24 of Australia, he did a long-term charter agreement with the  
25 Academy of Sciences and he ran tourist dives to *Titanic* and

1 hydrothermal vents very successfully for a number of years. He  
2 and I were friends. We ultimately went in as partners on the *Deep*  
3 *Rover 2* submersible system and bought them, although I never was  
4 involved with any tourist dives on those. He did that himself.

5 But at that point it became more convenient for me for my  
6 subsequent building operations at *Titanic* and at the hydrothermal  
7 vents to essentially sub-charter from him. So he had the primary  
8 relationship and then I would just buy time from him. Whenever I  
9 was using the system, which might be for 4 weeks, 6 weeks,  
10 something like that, I would have members of my team diving in the  
11 subs. They were technically not paying tourists. They were  
12 basically paid employees of the film who were along because they  
13 were historical experts or they were marine forensic experts on  
14 the wreck site. Or in one case we had a marine biologist who was  
15 studying the rustical formations or we even had some jet  
16 propulsion laboratory people who came to run a laser spectrometer  
17 in the hydrothermal fields as part of a search for life kind of,  
18 you know, Earth analog program. We had astronauts. We had -- I  
19 mean, and not as a gimmick. I mean, we were doing a NASA -- a  
20 joint project with NASA for Earth analog studies of, you know,  
21 essentially human factors in -- you know, so they were all  
22 sanctioned science observers essentially. I never messed with  
23 paid tourists. But my colleague that I kind of subleased from, he  
24 did that very successfully for a number of years and completely  
25 safely.



1 Q. And just to clarify, sir, was that the *Mir* subs or was that  
2 other platforms with the tourists?

3 A. Both the *Mir* subs and the *Deep Rover* platform. Because he  
4 would -- when I wasn't using it for filming, he'd operate it for  
5 his tourist operations.

6 Q. Thank you. I appreciate the answers and the time on that.

7 MR. [REDACTED] All right. Mr. [REDACTED] any further questions  
8 from your side?

9 LCDR [REDACTED] I do have a few more, sir, if you can bear with  
10 us for just a little bit longer.

11 MR. [REDACTED] Yeah. No problem.

12 BY LCDR [REDACTED]

13 Q. I kind of wanted to do some questions specific -- first -- I  
14 want to get to some OceanGate specific questions. I know that you  
15 had already stated and your representative had basically told me,  
16 you know, you didn't really -- you didn't know Stockton Rush well  
17 and you didn't deal much with OceanGate. But before I get into  
18 that, I want to talk really quickly about maintenance of your  
19 submersible in storage. Obviously you've talked about safety and  
20 you being the sole occupant of the *Deepsea Challenger*. You  
21 want -- everything's about safety. How did you handle it? How  
22 did you store it? How did you move it around the US? How did you  
23 get it to where you needed to get it? Like talk to me about those  
24 types of logistics.

25 A. Well, curiously enough, the sub was being moved by a truck

1 once and the brakes on the truck trailer caught fire and then  
2 burned the sub, burned part of outer ferry of the sub. So we had  
3 to repair the sub thanks to a failure of, you know, some trucking  
4 company to have good brake maintenance. No, you know, the sub  
5 would be trucked around as needed. We didn't -- we never flew it  
6 anywhere. Or it would be moved on a ship as freight.

7 In terms of maintenance, there was a whole DMOB on a  
8 protocol. We had to take the batteries out. We had to safe the  
9 whole battery system. We had to open it up so that all of our  
10 corrosion inspections could be done, done with a borescope and so  
11 on. There were different levels of disassembly that you'd want to  
12 do to inspect it. Not necessarily go for -- because, you know, we  
13 weren't in class so we couldn't really get out of class and we  
14 only dove it for the one series of dives. But even to preserve  
15 future capability, we basically did a, pretty much a full  
16 disassembly and inspected everything more as sort of a post-  
17 mission analysis, you know, to look at how the -- if the  
18 penetrators were showing any signs of corrosion; they weren't,  
19 fortunately. If the hull was, if the hatch was, etc. We took the  
20 whole thing apart, every nut and bolt, at Woods Hole with their  
21 engineering team and my engineering team working together for  
22 about a week. Took it all apart, put it all back together. And  
23 that was more in the nature of a technology transfer. However, if  
24 we had intended to dive the sub again and/or go for classification  
25 on that experimental vehicle, we would have done pretty much the

1 same thing in any case.

2 And I would recommend a full disassembly of any experimental  
3 vehicle after an operation, after any -- you know, if you're at  
4 sea for a month or 2 months or something like that, there should  
5 be definitely certain inspection points. At the very least, you'd  
6 have a protocol where you take out the viewport and you inspect  
7 the seat and then you reinstall it. You'd have a kind of a  
8 maintenance protocol like you would on an aircraft, like on a  
9 helicopter, you know, mean time to failure, number of cycles, all  
10 of those things for every part on board.

11 And we basically had that in the abstract. We just never got  
12 to the point where we were going to go operational again. That  
13 hasn't happened yet. And I say yet because we might still put  
14 that thing back in the water someday. But right now I've got a  
15 year and a half of finishing *Avatar 3* ahead of me, so it's not  
16 going to happen in the next year and a half.

17 Q. I understand, sir. And I'm going to guess this is needless  
18 to say, but storage of the vehicle should be in an environmentally  
19 controlled or -- in an environmentally controlled location?

20 A. Absolutely. Yeah, yeah. Look, I know where you're going  
21 with this because they left the thing outside in Newfoundland for  
22 the winter. And I think that that might have been a contributing  
23 factor to failure. I mean, it's my strong hypothesis that water  
24 ingress at a molecular level invaded and followed the fibers of  
25 the carbon fiber. It's very hard to imagine what's happening with

1 water molecules at that kind of pressure, but they can go  
2 anywhere. And I believe that they migrated along the pathways of  
3 the fibers and created a delamination problem. And if there was  
4 water ingress from a previous season of diving and the sub was  
5 left outside in subfreezing temperatures and that water was able  
6 to expand, that could have created additional delamination. I  
7 mean, rocks weather because of water in the rocks freezing and  
8 they break. You know, if you can break rocks, you can break a  
9 pressure hull. So that may have been a factor.

10 I think the other places you guys should be looking is at the  
11 end mating seat between the raw end of the carbon-fiber cylinder  
12 and the titanium end flange. Because that's -- they just  
13 basically glued it on, and that's not how pressure seals work.  
14 And they also did like a Rhino coat around the outside of the  
15 entire cylinder, which is -- that's great for your pickup truck  
16 bed, not so good for a pressure hull. To me, that's right where I  
17 would go.

18 I don't mean to say too much here, but when I heard -- I went  
19 and pulled the emails from the morning -- it was actually the  
20 morning after the incident because I had been at sea the entire  
21 previous day and so I first heard about it at around 9 a.m. the  
22 Monday morning. And the first thing I heard was that they had  
23 lost comms and tracking. It's like, oh, they imploded. I  
24 literally, that -- okay, they imploded. Just because you don't  
25 lose comms and tracking at the same time. They're independent

1 systems and the only way to lose them both is to have a  
2 catastrophic failure. So, you know -- and it took me two phone  
3 calls to confirm that they Navy heard a bang at that location. So  
4 it's like, okay. So I just sent out an email blast to all my  
5 tight circle of people and said we've lost our friends, hoist a  
6 glass tonight in their honor. That was on Monday. It was Monday  
7 at 9:30 a.m. So to me there was never a doubt that it was sitting  
8 in pieces at the last known position, which is why I strongly  
9 advocate for having an ROV available like at the ship.

10 Q. Yes, sir.

11 A. Or nearby at the worst-case scenario, you know --

12 Q. Yes, sir.

13 A. -- to either assist or confirm.

14 Q. Appreciate that. Just a few more questions. So just to kind  
15 of -- obviously the reason why we're here is kind of just as part  
16 of the investigation for OceanGate and *Titan*. Did you ever have  
17 any interactions with Stockton Rush with regards to the *Titan*  
18 submersible?

19 A. He invited me to come out and make a dive and which I  
20 declined. Two reasons: one, I was too busy; and two, I didn't  
21 like the design.

22 Q. What didn't you like about the design?

23 A. I don't like cylinders. I like spheres. Cylinders can be  
24 used down to a certain depth, but not a depth class -- or like the  
25 4,000 meter depth class, I would say. Just in general, it's a bad



1 idea. Specifically, I didn't like the carbon fiber. I had  
2 already -- I knew very well the design specs for [REDACTED]  
3 submersible, which I think he called -- I can't remember what  
4 he called -- *Deep Flight 2*, I think it was, *Deep Flight 2*. And,  
5 you know, it had an end flange and it had a sapphire dome and it  
6 had a carbon-fiber cylinder and a titanium hemispherical end cap  
7 on the other end. So it was basically a big get cap, very much  
8 like the *Titan* sub. And I hated the idea of wound carbon fiber as  
9 a pressure vessel for extreme depth. I mean, maybe you can get  
10 away with it for a couple thousand meters, something like that,  
11 but it's just not the right material for the job. It's a non-  
12 isotropic material. I'm sure you're hearing this from everybody.

13 I never specifically told Stockton it was a bad idea. I did  
14 specifically tell [REDACTED] that it was a bad idea and he was going  
15 to die if he dove that thing -- and he never did, which I think is  
16 interesting -- or he dove it deep. I think ultimately his sub  
17 dove to a depth of about 1,000 meters, you know, a couple times.  
18 It never really, it never really did what it was supposed to do,  
19 which go to 11,000 meters -- or 10,900, which is really about the  
20 deepest spot.

21 I didn't like the dissimilar materials mated, you know, at  
22 the place where the cylinder interfaces with the end flange just  
23 because your differential bulk modulus, when you start dealing  
24 with extreme pressures, they compress at a slightly different  
25 value, which introduces shear forces at that place of, you know,

1 maximum interface pressure. You're introducing shear forces,  
2 which essentially on a microscopic level creates tension failure,  
3 things pull apart. When you start pulling apart a wound carbon-  
4 fiber material you start creating a pathway for water ingress.  
5 You know, there's just a lot of problems with that concept.

6 And they did it to save weight, but there are no shortcuts  
7 when you're dealing with pressure. You need -- your hull needs to  
8 be spherical and it needs to be an isotropic material, whether  
9 that's titanium, steel, glass, acrylic, whatever it is. It's an  
10 isotropic material so it behaves the way -- it can be predicated  
11 in an FEA. Then you test, obviously you test. But you can't  
12 predict the behavior of a, you know, a material made up of  
13 different things, you know, the bonding epoxy and the carbon fiber  
14 and how they interact with each other. You know, if you've got  
15 steel, if you've got acrylic, you know the number of cycles that  
16 it can withstand safely and it's usually in the hundreds if not  
17 thousands. And carbon fiber you have no idea. And you add to  
18 that the fact that they didn't have inspection protocols with  
19 ultrasound or, you know, some other sort of radiography or any  
20 kind of diagnostics operationally, that's just a recipe for  
21 disaster.

22 Q. And you had stated earlier that you had a very good  
23 relationship with P.H.

24 A. P.H., yeah.

25 Q. Did you ever discuss his interactions with OceanGate and

1 Mr. Rush?

2 A. No. I had sort of lost track of what they were doing, to be  
3 perfectly honest. I didn't even know until I got the roster of  
4 people involved in the incident that P.H. was on board. I knew  
5 him from way back in the day from my first expeditions at *Titanic*.  
6 And we'd compare notes, and he's the only other person in the  
7 world that's piloted a remotely operated vehicle inside the  
8 *Titanic* wreck. So we'd get together and we'd look at each other's  
9 footage and we'd talk about what we thought was happening inside  
10 the wreck, the marine forensics of it. You know, and there was a  
11 little bit of a friendly competition because, you know, I think he  
12 had 37 *Titanic* dives and I had 33, and so, you know -- but we were  
13 pals, you know.

14 Q. Yeah.

15 A. Plus he's French, so we'd get together and, you know, drink  
16 wine and talk about our adventures. You know, I don't want to say  
17 as a matter of public record what I think about P.H. being  
18 involved with this. The only thing I'll say is he wasn't an  
19 engineer. You know, he believed the assurances. That wasn't his  
20 thing. He was a pilot.

21 Q. Understood. Thank you. I appreciate that.

22 I was going to ask you earlier how important the modulus is  
23 in the submersible, but I think you just covered that there with  
24 that one.

25 A. Dissimilar materials at a mating, at a high-pressure mating

1 seat are not a good idea unless you really know what you're doing.  
2 So an acrylic port going into a steel or titanium conic frustum,  
3 you've got to understand what's happening at that boundary, at  
4 that pressure interface. And we came to understand that very  
5 well. We even -- sometimes we'd use a lubricating material so  
6 that it could cold flow within the seat in a predicable way. We  
7 even did something that was pretty radical that even [REDACTED]  
8 hadn't thought of, which is that we slightly radiused our cone,  
9 our acrylic cone so that it actually had about -- I think it was  
10 less than a millimeter, maybe a millimeter or two, at the [REDACTED]  
11 it wasn't fully seated at the [REDACTED] It was only seated on the  
12 outside part of cone so that under pressure as it cold flowed, it  
13 expanded into the rigid, relatively rigid seat. And that reduced  
14 the stress riser that showed up at above 10,000 psi. So we were  
15 seeing a stress riser, we were seeing spalling -- not spalling, it  
16 was actually a conchoidal fracture. We said, well, we can't have a  
17 conchoidal fracture in our dome plate, that's probably bad form.  
18 So I actually figured out the idea that we could gently relieve it  
19 by machining the cone and then the cone would seat.

20 But you've got to get into the dynamic, you got -- I mean, my  
21 engineering partner, [REDACTED], is much better at this than I am,  
22 but he can literally think at a molecular level of what's  
23 happening. And when you have a differential bulk modulus at a  
24 mating seat, you've got to really understand what's going on  
25 there. And I don't think they did. And they obviously -- it's a

1 matter of public record that they didn't even believe their own  
2 chief engineer and fired him and sued him and, you know, all that  
3 crap, so -- you know.

4 I think what you've got is cultural failure, you know, is not  
5 putting safety first, not putting safety as the highest priority.

6 [REDACTED]  
7 [REDACTED]  
8 [REDACTED]  
9 [REDACTED]

10 [REDACTED] You've got to be  
11 paranoid about everything that can go wrong. You sit and you  
12 think about it and you dream about it and you wake up in the  
13 middle of the night thinking about what can go wrong, and then you  
14 engineer against it. And you spend years thinking about what can  
15 go wrong and then you engineer against it. And then operationally  
16 you think about everything that can go wrong and you build your  
17 operational protocols. You know, it's the same thing as in  
18 aerospace or in space. You know, you never want to be dealing  
19 with the thing you predicted. You only want to be dealing with  
20 the thing that your imagination couldn't have predicted.

21 Q. Thank you, sir.

22 A. And it's just a philosophy. So, you know, I think that, you  
23 know, as you talk to people I'm sure you're getting a sense of  
24 moral outrage that these guys didn't have that. But it's  
25 definitely a failure of culture of that operational group.



1 Q. Understood. Mr. [REDACTED] I don't have any further questions.

2 LCDR [REDACTED] Mr. [REDACTED] do you have any further questions?

3 MR. [REDACTED] You know, if I might, just one follow-up from  
4 your line of questioning.

5 BY MR. [REDACTED]

6 Q. In all of your dives to *Titanic*, did you interact at all with  
7 Transport Canada from ship safety point of view?

8 A. I didn't personally. I'm not sure -- I couldn't say if  
9 somebody in my organization did or not. You know, we had to  
10 deal -- I mean, we had Coast Guard, we had Canadian -- well, the  
11 first time we went out with the Russians in waters that were  
12 international but adjacent to Canada and operating out of a  
13 Canadian port, we had -- you know we had Orions going around us  
14 dropping sonar buoys to keep an eye on what we're doing.

15 Q. Okay. Yeah.

16 A. You know, so there was a high level of scrutiny, let me put  
17 it that way. No sonar buoys showed up on our second expedition in  
18 2001. In terms of interfacing with the Canadian Safety Board, no.  
19 I didn't have any direct communication with them.

20 MR. [REDACTED] Okay. Thank you again for your time today.

21 MR. [REDACTED] Yeah.

22 BY LCDR [REDACTED]

23 Q. All right. Mr. [REDACTED] I had one question I forgot to ask.  
24 From an egress standpoint, in all the submersibles that you've --  
25 you know, you're familiar, was it always like a single egress

1 point available?

2 A. Yes. Every sub I've been involved with, deep sub, has a  
3 single egress point. You may have multiple protocols for how to  
4 get people safely out of the sub, but it's all about that hatch.

5 Q. Okay. And then a follow-up to that, sir. Was there ever a  
6 situation that you're aware of in any of those submersibles where  
7 you would have to have an outside extract, you know, take off the  
8 hatch, where you are essentially bolted in or --

9 A. In my sub, I was bolted in. I could not, I could not get  
10 out. But we talked about this for 2 years, about the various  
11 scenarios. And ultimately, we came on the side of it being  
12 actually safer that way, and to -- you pile your chips in  
13 different areas. You can have self-egress, but where does that  
14 put you? It puts you with a sub that's now open to the sea and  
15 flooding and sinking versus making sure that you have a safe  
16 capture environment for the vehicle, either that it's being held  
17 at the surface or whatever and a controlled egress. So, you know,  
18 there's different schools of thought on that. Because being --  
19 sitting outside the sub with a ham sandwich, sitting on top of a  
20 sub that's that big at the top, in an open sea state nowhere near  
21 you're other people is also not a very desirable situation,  
22 especially if it sinks because you opened the hatch. So, you  
23 know, you're faced with some hard choices on an experimental  
24 vehicle.

25 On a tourist sub I think you have to have multiple protocols.

1 The Russians did. They had -- they could get out of the sub. The  
2 sub had very little freeboard. You open the hatch, sub's going to  
3 sink. Wave will go in, it'll get negative, and then it'll be a  
4 self-propagating reaction. And that happened to *Alvin* back in the  
5 '60s before they put a sail on *Alvin* to prevent that from  
6 happening in the future. The Russians has an inflatable sail,  
7 which is an interesting concept, that would accordion up. So  
8 there was a gas feed, I don't know, probably just nitrogen, dry  
9 nitrogen in a bottle, and it would inflate and it would sit about  
10 a meter because the sub had very low freeboard. And so then they  
11 could actually egress on their own and get outside the sub.

12 With the *Deep Rover 2*, the way it worked, because it  
13 functioned like an air bell, the hatch swung down. So the air  
14 captured in it, the sub stayed, the hatch swung down. Because  
15 [REDACTED] said, if we have a low freeboard vehicle and you  
16 open the hatch at the surface and the water can ship in, you're  
17 going negative and you're going to lose the vehicle and you might  
18 not get everybody out. So he said, I'm going to do the reverse.  
19 And this was actually embraced for a while as a concept in the  
20 submersible design community. But now you're opening -- you have  
21 to equalize pressure, it's about 7 -- 6 or 7 psi, and then you can  
22 open the hatch and it'll drop open.

23 We did a lot of safety training around how to do that. We  
24 always had a -- we always contemplated having a support diver  
25 there, but you could have done it on your own if you had to. You

1 could even theoretically do it if you were grounded on the [REDACTED]  
2 in less than, you know, 100 feet of water. You could  
3 theoretically get out of the vehicle on the [REDACTED] That was  
4 abandoned by the community and everybody went to top hatch  
5 scenarios. And that's kind of where it sits today, that you get  
6 out the top.

7 Q. Okay.

8 A. And I wasn't involved in any of those analyses in that egress  
9 space. We had our own egress protocols for the *Deepsea Challenger*  
10 if we couldn't recover it. Because that was -- that would've been  
11 a bad day. If you can't get the sub out of the water and the  
12 egress point is submerged, how do you get out? Well, we had a  
13 protocol for that, but it required support divers.

14 Q. Okay. Thank you, sir. I appreciate those explanations. And  
15 then did you ever see a hatch that was not a top hatch, like the  
16 *Titan* design, where it was front dome that --

17 A. *Titan* was basically kind of a clamshell design. There were a  
18 couple of subs historically where the entire -- they would -- two  
19 hemispheres would part and be mated before the dive. And I  
20 actually think that the original *Deep Rover 1* worked that way, and  
21 there are some other subs that work that way. I think the *Deep*  
22 *Worker* sub basically is a cylinder with a dome on top, an acrylic  
23 dome on top that opens that functions as a hatch for a single  
24 occupant vehicle. So that's not that uncommon an idea. That's  
25 even an idea that I explored for the *Deepsea Challenger* at one

1 point, which is that your joining of your two halves of your  
2 pressure vessel is also your hatch seat essentially. In any kind  
3 of hatch, whatever it is, if it's a high pressure mating seat,  
4 which it is, you have to inspect very carefully because even the  
5 finest piece of grit causes a slight separation in that immediate  
6 region between and you need -- it's a steel-to-steel seat. I'm  
7 sure you've had this explained. But there's an O-ring seal that  
8 does virtually nothing below 30 or 40 feet. Once external  
9 pressure has seated the hatch, once you've started your dive, that  
10 O-ring is irrelevant. That O-ring only really works in the top  
11 few feet of water before the pressure is really acted. After  
12 that, it's a steel-to-steel or whatever your material is seat  
13 that's driven by pressure. So you ask the ocean's pressure to  
14 work to keep the water out, and that's how all these ideas work.

15 So the idea that you could do it at that scale, I guess it's  
16 probably, what, a 2-meter diameter interface? It's -- you know,  
17 it wouldn't be my first choice, let me put it that way. Because  
18 now you've got a much larger mating seat that you have to  
19 carefully inspect and make sure it's joined and aligned properly  
20 and all that. It wouldn't daunt me as an engineering problem if  
21 you decided to do it that way. And I don't think that that's  
22 where their failure mode lay at all. I also don't think it was  
23 the acrylic port. I think the acrylic port just got knocked out  
24 by the internal in-rush of water at hypersonic speed, just blew it  
25 out the front, broke all the retaining bolts. That's my



1 hypothesis, because I know it came up without it. And at first it  
2 was like, oh, might have been the port. But I don't think it was  
3 the port. But you guys will suss that all out. I look forward to  
4 reading the report. Let me put it that way.

5 LCDR [REDACTED] Sir, no, thank you very much. That is the last  
6 question I had. I really appreciate your time.

7 MR. [REDACTED] Yeah.

8 LCDR [REDACTED] I look -- we look forward to providing a report  
9 to the people and, obviously, after we move forward with our  
10 marine board hearing, which will hopefully be soon, so --

11 MR. [REDACTED] Okay.

12 LCDR [REDACTED] But, Mr. [REDACTED] I want to thank you for your  
13 time. Thank you for allowing us to speak to you and kind of run  
14 through your history and all your expertise. We greatly  
15 appreciate it. If there's anything else that comes up that you  
16 can think about or something that comes to light that maybe you  
17 wanted to touch on, I've been in contact with [REDACTED].

18 MR. [REDACTED] Yeah. Yeah.

19 LCDR [REDACTED] She has my email. And if you need anything,  
20 feel free to reach to me and then we can get back in touch.

21 MR. [REDACTED] Okay. Yeah, I'll look. I think this has been  
22 pretty thorough going, guys. I appreciate it. I would strongly  
23 recommend talking to [REDACTED] if you haven't already. He's far  
24 more expert than I am on the day-to-day operations of tourist  
25 class vehicles. That's his main business. And he wrote most of

1 the protocols that are currently used by -- you know, are accepted  
2 by the community and so on, and he can speak to it nuts and bolts  
3 at a level that I can't.

4 LCDR [REDACTED] Yeah. I've spoken with [REDACTED], and we're  
5 looking at speaking with him at great length as we move more into  
6 the future of the process here. But absolutely.

7 MR. [REDACTED] Yeah. Yeah. No, he'd be a great resource.

8 LCDR [REDACTED] Thank you, sir. And with that --

9 MR. [REDACTED] Thank you, Lieutenant Commander. Thank you,  
10 gentlemen. It was great talking to you and I wish you luck in  
11 your pursuit of the truth.

12 LCDR [REDACTED] Thank you, sir. Good luck.

13 MR. [REDACTED] Thanks. All right. Bye now.

14 LCDR [REDACTED] Bye.

15 (Whereupon, the interview was concluded.)  
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CERTIFICATE

This is to certify that the attached proceeding before the  
NATIONAL TRANSPORTATION SAFETY BOARD

IN THE MATTER OF:            LOSS OF THE SUBMARINE *TITAN*  
                                      IN THE NORTH ATLANTIC OCEAN  
                                      ON JUNE 18, 2023  
                                      Interview of 

ACCIDENT NO.:                DCA23FM036

PLACE:                        via Microsoft Teams

DATE:                         July 26, 2024

was held according to the record, and that this is the original,  
complete, true and accurate transcript which has been transcribed  
to the best of my skill and ability.



Transcriber